Studsvik

NRC PRE-SUBMITTAL MEETING

OPEN SESSION

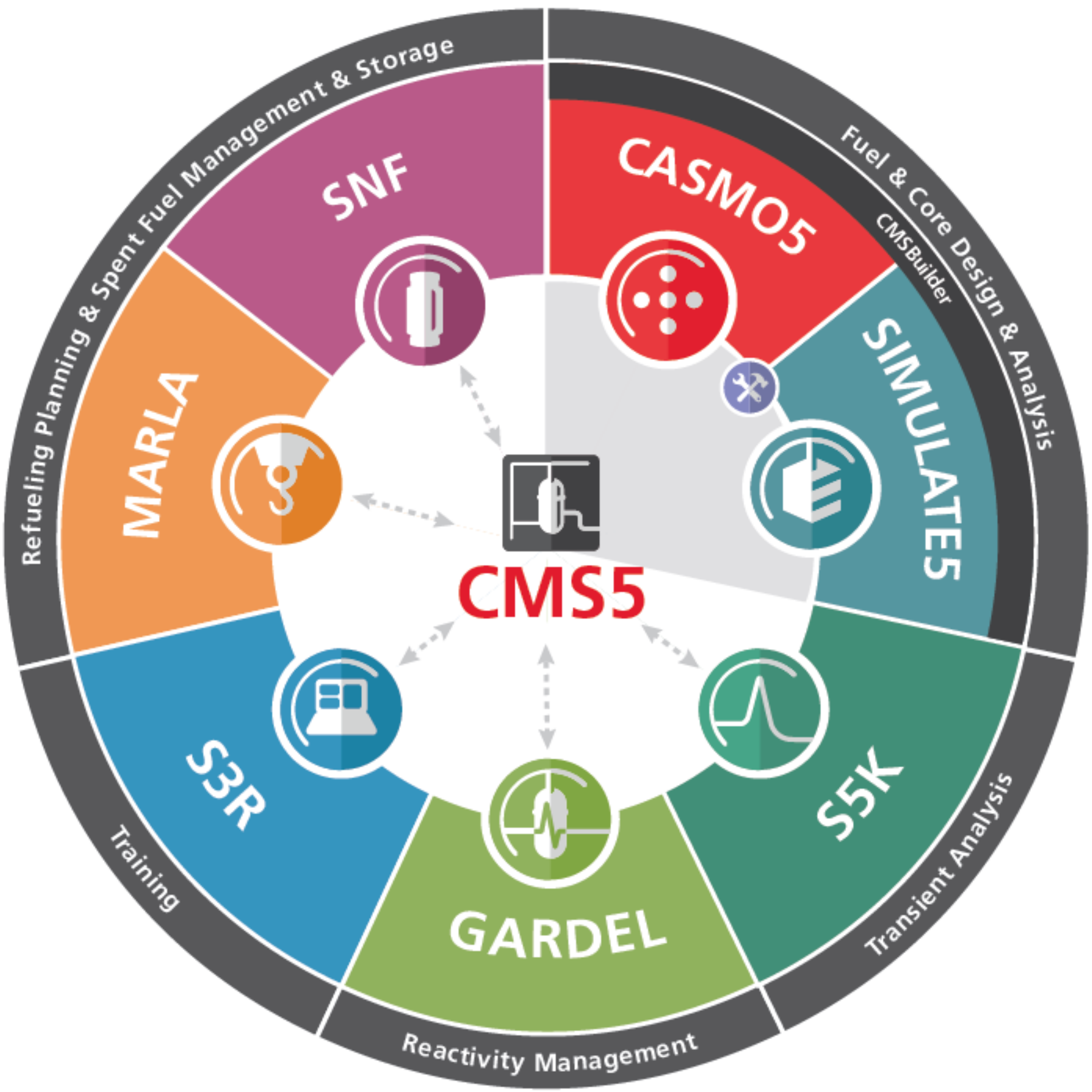
23 October 2023, Rockville, MD

WHO IS STUDSVIK SCANDPOWER (SSP)?

- Reactor Core Analysis Software & Services for ~40 years
- Over 700 man-years experience in the Nuclear Industry
  - Nuclear Utilities
  - Fuel Vendors
  - Nuclear Power Plants
  - SMR startups (LWR)
  - National Labs
  - Safety Authorities
  - Universities
  - ~41 Nuclear Engineers (Ph.D., M.S.)

- Offices world-wide:
  (U.S., Sweden, Germany, Japan, China)

SSP'S KEY OFFERINGS



Software developed for modeling the nuclear fuel lifecycle:

- ✓ Fuel and core design
- ✓ Online core monitoring
- ✓ Transient and safety analysis
- ✓ Real time core simulation
- ✓ Refueling / core shuffle
- ✓ SFP storage safety analysis and planning
- ✓ Cask load campaign planning
- ✓ Long-term isotopic data management

Software in use at more than 200 nuclear power plants

Users prefer Studsvik software due to vendor independence, high fidelity, ease of use, graphical interfaces, automation

BACKGROUND

SSP is the vendor of the CMS5 Steady-State LWR Code Suite:

- 2D Lattice code : CASMO5 (586 group E7R1 lib, Equiv. Theory, MoC, CRAM)
- Linking code: : CMSLINK5 (extensive case matrix)
- 3D Advanced nodal code : SIMULATE5 (Multigroup, fully analytic, hybrid micro-model)

- CMS5 software is maintained under a 10 CFR 50 App B / 10 CFR 21 /NQA-1 Quality Assurance Program

- On Dec. 15, 2015 SSP submitted a Topical Report (TR) which was reviewed and approved by the USNRC on Sept. 15, 2017:

"FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION TOPICAL REPORT SSP-14-P01/028-TR, "GENERIC APPLICATION OF THE STUDSVIK SCANDPOWER CORE MANAGEMENT SYSTEM TO PRESSURIZED WATER REACTORS" STUDSVIK SCANDPOWER INC. PROJECT NO. 816" ***(ML17236A419)*** *"*

- *"The NRC staff has found that TR SSP-14-P01/028-TR, is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR."*

- The safety evaluation of the CMS5 Code system consisted of the following sections:

  1. CMS5 Code descriptions
  2. CMS5 Code Validation and Verification
  3. NUF (Nuclear Uncertainty Factors) Methodology
  4. NRF (Nuclear Reliability Factors) from engineering/physical arguments
  5. NRF Generation and Generic NRFs

WHAT THE SSP TR ASKED FOR:

- PWR Fuel with U-235 enrichment in UO2 up to **10 w/o of U-235**;

. . .

- Benchmarking of CMS5 system has been performed for burnups of peak average assembly burnup up to **64.5 gigawatt days (GWd)/ metric ton of uranium (MTU), peak average fuel rod burnup of 72.6 GWd/MTU, and peak pellet burnup of 78.2 GWd/MTU;**

- Back to the SSP SER:
  "Various sections of this SE will address the limits of applicability of the CMS5 system that are stated above. All these limits may not be found to be acceptable and will be based on the assessments described in this document. The NRC staff will either restate the limits of applicability above or recommend new limits in Section 4.0, "Limitations/Conditions" of this SE."

4.0 LIMITATIONS/CONDITIONS OF SER

"The NRC staff limits the applicability of the Studsvik Scandpower Core Management System (CMS5) for PWRs TR, SSP-14-P01/028-TR-P to the following material or conditions of fuel, cladding, poison, and other core materials specified below:

- *Fuel and Poison • Uranium Oxide fuel enriched up to **5 wt% U-23**5 • Pin lattice geometries ranging from 14x14 to 17x17 including both large and small water hole designs • The typical range for nominal density between 10.3 and 10.9 g/cc (or between 0.94 and 0.985 as a fraction of theoretical density). • Integral burnable absorber Gd2O3 with range up to 12 percent as a mass fraction of the total fuel weight. • Integral burnable absorber (IFBA) ZrB2 • Discrete absorber types WABA, B4C-AlO3, Boron Silicate Glass, and Hafnium suppressor rods*

- *Cladding • Zircaloy-2, Zircaloy-4 • ZIRLO and Optimized ZIRLO • M5 • TVEL cladding materials (E110 and E635) • Japanese cladding material (NDA and MDA) • CMS5 code system can handle Zr based cladding materials with trace elements of other materials (such as Nb, Sn, Fe, Cr, Ni, and O)*

- *Structural Materials (but not limited to) • Stainless Steel, Inconel-718, Inconel-750*

- *Fuel Burnup: CMS5 is benchmarked to :*
  - Peak average assembly burnup of 64.5 GWd/MTU
  - Peak average fuel rod burnup of 72.6 GWd/MTU ←
  - Peak pellet burnup of 78.2 GWd/MTU

*However, the NRC staff has restricted the rod average fuel burnup up to **62 GWd/MTU for all currently approved types of cladding**. For fuel designs with new cladding material, change in the fuel rod burnup shall be subjected to the burnup approved by the NRC staff for the new fuel/cladding design.“*

. . .

“The [NRC] concludes that the CASMO5/SIMULATE5 models together with the <u>generic NRFs</u> are suitable for core design, analysis, and depletion calculations.”

Note, the area that SSP is interested in is narrow in scope and limited to steady-state neutronics analysis and not other areas such as LOCA methods, or fuel thermal mechanical methods, etc.

WHAT SSP IS CURRENTLY LOOKING TO PRESENT TO NRC FOR REVIEW –THREE MINOR REQUESTS:

1. Increase U235 enrichment limitation from **5 wt%** to **10 wt%**

2. Increase rod average burnup limit from 62 MWd/kg to fuel vendor specified limit (determined by individual product line)

3. Acknowledge that the current CMS5 Methodology as outlined in the current SER can be applied to boron controlled, PWR SMRs that are similar in design (both fuel and reactor) to the wide range of PWRs benchmarked in the SSP TR (7 units/63 cycles).

Let us consider these requests one by one:

REQUEST 1: REVISION TO ENRICHMENTS <= 10WT%

- Current limit from SER:
  - "Uranium Oxide fuel enriched up to 5 wt% U-235"
  - "The typical range for nominal density between 10.3 and 10.9 g/cc (or between 0.94 and 0.985 as a fraction of theoretical density)." (Note that density will change with enrichment)
- Why the limit should be increased?
  - Industry is moving to higher enrichment and density fuel.
  - LTAs of ~6 wt% are planned to be loaded in Vogtle-2 (2025).
  - Increasing the SER limit on enrichment allows operators to analyze and license new PWR fuel product lines using licensed CMS5 methodology.

REQUEST 1: REVISION TO ENRICHMENTS <= 10WT%

There is precedence for the USNRC to approve methodologies similar to CMS5 for higher enrichment:

(ML19308C037 –WCAP-18443-NP)
"Qualification of the Two-Dimensional Transport Code PARAGON2" July 2021

(ML21035A075 –ANP –10353-NP)
"Increased Enrichment for PWRs" Jan. 2021

There are no methodological limitations in CMS5 with respect to enrichment

- Evaluated neutron cross section U-235 is well-known and CASMO5 586 energy-group library capture any slight spectral difference.
- Advanced nodal methods in SIMULATE5 involving multi-group and spatial rehomogenization are capable of capturing any neutronic impact from higher enrichment fuel.

REQUEST 1: REVISION TO ENRICHMENTS <= 10WT%

- CASMO5 generates homogenized data for downstream calculations using single and multi-assembly calculations (standard two-step approach)
  - Licensed methodology based on E7R1 library, use the same library for revised limit.
  - Comparisons to critical experiments at cold conditions can provide benchmarking for CASMO5 and <= 10wt% revision.
  - Several experiments with enrichments > 5 wt% in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) are suitable CASMO5 benchmarks.
  - Benchmarking of CASMO5 can be buttressed by performing comparisons relative to high-order calculations (Monte Carlo, e.g. MCNP or SERPENT2)
- Enrichment plays no direct role in SIMULATE5 3D full-core nodal calculations

CASMO5 BENCHMARKING FOR HIGH ENRICHMENT

- Analyze Otto Hahn (6.6 wt.%) and Kurchatov (10 wt.%)

LCT	Cases	Organization	Enrichment	Inputs available	Comments
18	1	Winfrith	7	MONK	
47	3	Winfrith	3 & 7	KENO, MONK, CRISTAL	Mostly 3% fuel
76	3	Winfrith	3 & 7	MONK, KENO	Mostly 3% fuel
22	7	Kurchatov	10	KENO, MCNP, MONK	Hexagonal pitch
23	6	Kurchatov	10	KENO, MCNP	Hex, partially flooded
24	2	Kurchatov	10	KENO, MCNP	
25	4	Kurchatov	7.5	KENO, MCNP	Hex
32	9	Kurchatov	10	KENO, MCNP	Hex, up to 274 °C
70	12	Kurchatov	6.5	MCU-REA, CRISTAL, KENO	Hex
75	6	Kurchatov	6.5	MCU-REA, TVS-M, KENO	Hex
85	13	Kurchatov	6.5	MCU-REA, KENO	Hex
94	11	Kurchatov	4.4 & 6.5	MCU-REA, KENO	Hex
78	15	Sandia	6.9	KENO, MCNP, CRISTAL	
80	11	Sandia	6.9	KENO, MCNP, CRISTAL	
96	19	Sandia	6.9	KENO, MCNP, CRISTAL	
97	24	Sandia	6.9	KENO, MCNP, CRISTAL	Replacement rods
81	1	Otto Hahn	3.5 & 6.6	MCNP	
98	7	Westinghouse	5.74	MCNP	

REQUEST 2: REVISION TO MAX. BURNUP LIMIT

Current limit from SER:

"Rod average fuel burnup up to 62 GWd/MTU for all currently approved types of cladding"

Why should this limit be increased ?

There are no methodological limitations in CMS5 with respect to higher burnup

One of the more compelling reasons for the PWR industry to move to enrichments > 5 wt% is to allow for longer cycle lengths which will necessarily entail fuel going to higher burnup at time of removal.

There are currently ongoing industry efforts to raise the limits of these parameters to increase fuel utilization efficiency. Validating CMS5 over extended ranges of enrichment and burnup will certainly aid in the future implementation of these efforts.

Tying the max. burnup limit to the fuel vendor product line max. burnup limit, removes the arbitrary nature of the current limit, while still imposing a hard limit that has regulatory approval.

The case for higher enrichment and higher burnup go hand in hand

REQUEST 3: REVISION TO INCLUDE PWR SMRS IN SCOPE

- SSP requests that an explicit acknowledgement that the CMS5 code system is applicable to small SMRs as long as the following system design parameters are met:
  - Reactor design is a PWR (boron controlled)
  - Reactor fuel is a standard PWR design covered by the current CMS5 licensing basis or other extensions to the license, e.g. 17x17
- These types of reactors are considered a subset of the PWR designs covered explicitly by the current SER and are well within the CMS5 neutronic/thermal-hydraulic calculational envelope. There is nothing neutronically special or challenging about these designs.
- Advanced nodal methods in SIMULATE5 with multi-group and spatial rehomogenization are capable of modeling any neutronics effects in these SMRs.

REQUEST 3: REVISION TO INCLUDE PWR SMRS IN SCOPE

- The Safety Evaluation for the NuScale SMR (Ref. ML 18234A294) directly references the SSP SER implicitly underscoring that the USNRC has concluded that the CMS5 NUFs were applicable to this type of reactor (NuScale's approved nuclear analysis code and methods utilize CMS5).

- SSP only seeks acknowledgement of the CMS5 Methods and V&V decription and the NUF/NRF methodology of the SER are applicable and not the generic NUFs/NRFs that are reported.

- Leveraging previous TR submissions helps streamline both industry's workload and the USNRC review workload by removing redudant effort.

There are no methodological reasons that CMS5 can not be successfully applied to reactors of this type (and in fact it has been demonstrated to do so successfully).

PROPOSED SCHEDULE

Activity	Approximate Date
Pre-submittal Meeting	Oct. 23, 2023
Submission by SSP	Q1 2024
Acceptance for review by USNRC	~June 2024
Regulatory / Technical Audit (Idaho Falls,ID)	Q4 2024 - Q1 2025
RAI's from USNRC	Q3 2025
RAI response from SSP	Q4 2025
Approval by USNRC	~June 2026

- Comments:
  - Expedited review is *not* requested
  - Consistent with earlier SSP TR submittal, USNRC in-house review *is* requested

SUMMARY

SSP believes that approving the requested revisions to the SSP PWR Generic SER:

- Increased enrichment limit to 10 wt%
- Increased max. burnup limit be limited by the vendor fuel product
- Acknowledgement that the current CMS5 methods described in (TR SSP-14-P01/028-TR) can be applied to certain PWR SMRs that are within scope

would greatly benefit the current PWR industry, and the nascent PWR SMR industry, without compromising safety by providing easy to use, modern calculational methods while simultaneously helping to streamline the licensing process.

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